The Survey of Status Preventive Maintenance Implementation in Government-owned Laboratory in Indonesia

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Abstract

Every Laboratory is facilitated with adequate equipment to support its performance. Maintenance of laboratory equipment must be carried out correctly to ensure the data generated is consistent and reliable. One of the priorities that contribute to successful maintenance planning is preventive maintenance. This survey aims to analyze the current situation and the characteristics of preventive maintenance implementation across the Laboratory from different sectors in Indonesia, especially government-owned laboratories. Data collection was carried out randomly using a questionnaire and analyzed both quantitatively and qualitatively. The questions are designed based on the list formulated (variables) from characteristics in the literature review. This paper explores the Laboratory's preventive maintenance implementation based on their characteristics to support the understanding of their current situation. A radar diagram was generated showing the current situation of preventive maintenance implementation in laboratories.

Keywords
Laboratory, Government-owned Laboratory, Preventive Maintenance, Surveys

1. Introduction
Laboratories are the cradle of science and technology (S&T), safety, health, environmental protection, and energy conservation. Laboratories require an in-depth understanding of the specific needs, objectives, and risks associated with each of these needs. Some of these requirements are implemented explicitly to an industry (e.g., pharmaceutical, chemical) or an activity (e.g., manufacturing small volumes of high-potency products, working with biological agents). The Laboratory can be said to effectively run when it can manage flexibility, customer, production, value-oriented, and the primary job of its employees (Nurcahyo et al., 2018) so that every Laboratory is facilitated with adequate equipment to support its performance.

Laboratory equipment is defined as tools, consideration materials, consumables, reagents, and analytical systems (Yanikkaya-Demirel (2009) and Nurcahyo et al. (2018a)). Generally, laboratory equipment costs money and has a relatively high level of complexity. In addition, the test results are susceptible when there is a change in equipment performance. Maintenance of laboratory equipment must be carried out correctly to ensure the data generated is consistent and reliable. It also has an impact on the integrity and productivity of the work produced (Nurcahyo et al. (2019) and Bertholf (2017)). Therefore, laboratories must establish processes to detect and correct instrument malfunction.

Much of the literature has studied and discussed the problem of maintenance and replacement of progressively worse systems (Wang, 2002). Maintenance is the combination of actions over the life cycle of an item so that it can perform the expected function (BSI Standards Publication, 2017). The combination actions include all technical, administrative, and managerial actions. As a component of a facility maintenance system, preventive maintenance can optimize the useful life of all laboratory systems (Ganiron Jr, T. U. G., 2017). Preventive maintenance is defined as

maintenance accomplished intended to evaluate and (or) mitigate degradation and decrease the probability of failure of an item (BSI Standards Publication, 2018). Inspecting and fixing up damaged equipment and spare parts in routine maintenance could verify that lab equipment is secure. With understanding key process areas in laboratories, preventive maintenance is one of the priorities that contribute to successful maintenance planning (Nurcahyo et al., 2018b). Good maintenance contributes to cost-cutting measures by reducing the likelihood of repurchasing and early replacement. Furthermore, preventive maintenance is considered to be the most economical approach compared to other maintenance approaches, easily understood and justified (Stenstorm (2016) and Lipson et al. (1998)). Therefore, the implementation of preventive maintenance must be a priority in the maintenance strategy in the Laboratory.

This paper is organized as follows: section 1 presents introduction of this study, section 2 presents a literature review, section 3 presents a methodology, and section 4 presents data collection. Section 5 discusses the result and discussion of our survey. The last is section 5 about conclusion.

1.1 Objectives

This survey aims to analyze the current situation and the characteristics of preventive maintenance implementation across the Laboratory from different sectors in Indonesia, especially government-owned laboratories.

2. Literature Review

A product's performance deteriorates with time and usage or fails during the usage period. Maintenance secures a system of product degradation or recovers the product to its required functioning states combined with all technical and administrative actions, including supervision (Basri et al., 2017). Maintenance planning is essential that positively contributes to creating an effective maintenance activity (Nurcahyo et al. 2019).

Preventive maintenance consists of planned actions to minimize the likelihood of potential failure and improve system performance by intervening on components before an actual failure occurs (Zhu et al., 2021). Preventive maintenance proposes to manage or reduce the failure risk to the product, which may generate critical damage and intolerable cost (Ullah et al., 2021). Preventive maintenance actions take the time that could otherwise be used for laboratory activities, but delaying Preventive maintenance for laboratory equipment may raise the probability of product failure (Cassady and Kutanoglu 2005). The application of Preventive maintenance in laboratory testing helps achieve the quality objectives contained in the Laboratory and effectively run the testing laboratory (Nurcahyo et al., 2019). Preventive maintenance has several characteristics that we summarized in Table 1 and based on studying from various literatures.

Table 1. The Characteristics of Preventive Maintenance Formulated from The Literature

Characteristics	L1	L2	L3	L4	L5	L6	L7	L8	L9	L10	L11	L12
Organization Structure	X	X	X	✓	✓	X	X	X	X	X	X	X
Standardization of Maintenance Activities	X	✓	X	✓	X	X	X	X	X	X	✓	X
Maintenance Period	✓	✓	✓	X	✓	✓	✓	X	✓	✓	X	✓
Maintenance Technique	✓	X	X	X	✓	X	X	X	✓	X	X	X
Spare Part Management	✓	✓	✓	X	✓	✓	X	X	X	X	✓	✓
Information Management Systems	✓	✓	X	✓	✓	X	X	X	X	X	✓	X
Cost Structure	X	✓	✓	✓	X	✓	X	✓	X	X	X	X
Failure and Downtime	✓	X	X	X	✓	X	X	X	✓	X	X	X

Notes: L1: Aghezzaf, E. H., et al. (2007); L2: Moghaddam, K.S. (2009); L3: Laggoune, R., et al. (2009); L4: Oh, S.S., et al. (2012); L5: Ab-samat, H., et al. (2012); L6: Au-Yong, C. P., et al. (2014); L7: Duan et al. (2017); L8: Luan, X. et al. (2017); L9: Basri, E. I., et al. (2017); L10: Huang, J., et al. (2020); L11: Hardt, F., et al. (2021); L12: Niu, et al. (2021); ✓: considered; X: not considered.

Organization Structure

The maintenance manager must have the ability to create a division of labor for the maintenance tasks to be performed and then coordinate the results to achieve a common goal. Solving performance problems and taking advantage of opportunities can be achieved by selecting the right people with appropriate abilities, supported by continuous training and good incentive schemes, to achieve organizational success in terms of effectiveness and performance efficiency. The maintenance organization structure is how the various parts of the maintenance organization are structured, including defining the responsibilities and roles of units and individuals. The role of the workforce is in assessing the situation and determining the maintenance strategy to be implemented.

Standardization of Maintenance Activities

All processes from preventive maintenance are systematically standardized and made more effective based on failures and defects. PM can be directed in a structured and systematic way to monitor and improve the life of a system. An inspection strategy is needed to determine when one or more operating parameters should be controlled and whether the system is operating or failing.

Maintenance Period

The maintenance period is the duration considered of doing intermediate maintenance and major maintenance in the maintenance cycle. If the maintenance period is short, the risk of equipment and spare parts failure will be reduced, but frequent maintenance will increase costs and reduce equipment operating efficiency. On the other hand, if the maintenance period is long, equipment and spare parts failure will increase.

Maintenance Technique

Preventive maintenance is an essential maintenance technique typically applied in manufacturing environments to facilitate production flow and improve equipment efficiency.

Spare Part Management

The availability of spare parts is the main component that affects maintenance activities.

Information Management Systems

Preventive maintenance activities are planned and scheduled based on historical failure data. All processes from preventive maintenance are controlled and implemented with a connected system. Individual preventive maintenance operations are executed on the touch panel and stored in the data warehouse. Planned checks and other functions are performed via the CMMIS (Computerized Maintenance Management Information System) web interface.

Cost Structure

There are costs involved in maintenance such as: replaced, spare part costs, manpower costs, specific tools, and repair procedures.

Failure and Downtime

Preventive maintenance planning and scheduling are based on the main machine downtime where the machine is not operating due to a breakdown of more than 2 hours.

3. Methods

The literature review had been done to identify the characteristics of preventive maintenance in the Laboratory. In addition, brainstorming also carried out to expand the explanation about the preventive maintenance used by the laboratories and introduce their perspectives to achieve a better understanding. Then, the data was collected by surveys and the questionnaire was designed in this survey consists of three main parts: the project objectives, the questionnaire body, and the glossary. In this research, the questionnaires consist of 8 general questions and 13 in-depth questions which are considered importantly relevant to every variable that has been determined. The questions are designed based on the list formulated (variables) from characteristics in the literature review, as shown in Table 2. Then, the

variables will be used as an analysis for each characteristic. In determining the preventive maintenance applied by the laboratories for their daily activities and describing the variables under preventive maintenance study, the data in this research will be analyzed using qualitative and quantitative data where frequency counts are tabulated and converted to percentages. This method permits a researcher to collect data and describe the demographics with the help of statistical analysis.

Table 2. Variables of Preventives Maintenance

No.	Characteristics	Variables
1.	Standardizations of Maintenance Activities	Standard Operational Procedure Availability, Evaluation Standard Operational Procedure
2.	Cost Structure	Types of Cost in Maintenance, Benefits of Maintenance in terms of Costs
3.	Information Management System	Archive of Failure or Downtime Information, Application Used
4.	Maintenance Period	Long-term maintenance, Short-term Maintenance
5.	Organization Structure	Organization structure availability, Job understanding and perceptions, Team training
6.	Materials and Spare Parts Management	Materials and Spare Parts Availability
7.	Failure and Downtime	Understanding how to determine failure and downtime. Failure and downtime period
8.	Maintenance Technique and Tools	Tools Used

4. Data Collection

The data was collected by questionnaires that were distributed randomly through a google form. This study included thirty laboratories. The locations of respondents' laboratories are spread across several provinces in Indonesia. The Laboratory's ownership consists of the government and state universities with different years of establishment from 1955 to 2018, as shown in Table 3. However, two respondents did not include the year of establishment of the Laboratory in the questionnaire.

Table 3. Respondent Participation Based on Location, Established Date, and Ownership

Location	Respondent
West Java	10
Banten	14
West Sumatera	3
South Sumatera	1
Bali	1
Central Java	1
Total	30

Established	No. of Respondent
1955-1970	2
1971-1986	3
1987-2002	8
2003-2018	15
Total	28

Ownership	No. of Respondent
Government Agencies	20
State University	10
Total	30

The 30 respondents who took part in this study consisted of 4 laboratories, as shown in Figure 1. The most significant participation was the Process Control and Testing Laboratory, which consisted of 11 laboratories, the Research and

education laboratory, each with nine laboratories. The minor participation is in the Product Development Laboratory, where there is only one Laboratory.

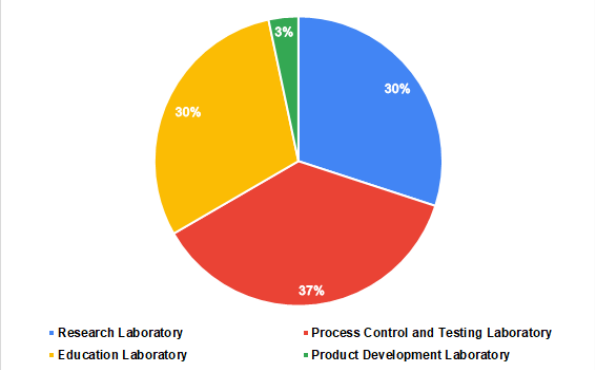

Figure 1. Participating Laboratory Segmented by Type

Respondents who filled out the questionnaire had several positions in the Laboratory. All respondent positions are involved in laboratory activities. The position of the respondents in the Laboratory is shown in Figure 2. Most of the respondents came from laboratory assistants, the Laboratory, and the head of the Laboratory.

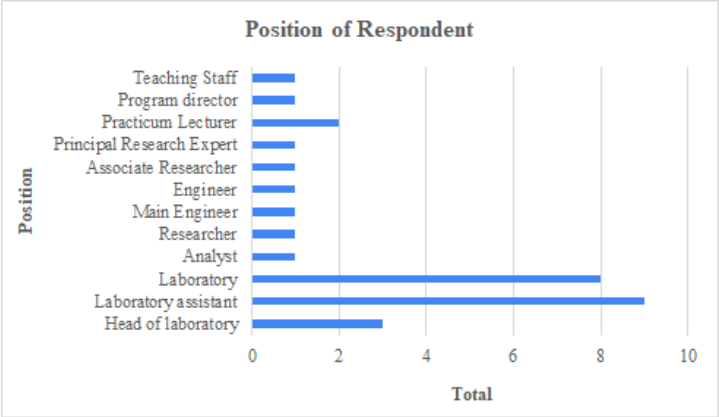

Figure 2. Position of Respondent

5. Results and Discussion

This section aims to illustrate the status of preventive maintenance implementation practice in the government-owned Laboratory by looking at the application of the current situation and its characteristics.

5.1 Characteristics of Preventive Maintenance Implementation in Laboratory

We discuss the preventive maintenance implementation in laboratory based on characteristic and its variable listed in Table 2.

Organization Structure

We survey the avalilability the organization structure and the result shows that 20 respondents (67%) strongly agree, and nine respondents (30%) agree that Laboratory maintenance activities should define individual responsibility and role in the organizational structure. However, one respondent stated that their Laboratory does not clearly define the responsibilities and roles of individuals in the organizational structure in Laboratory maintenance activities.

In order to understand their responsibilities and roles, 14 respondents stated that they run preventive maintenance training every year. In comparison, every three respondents stated that they run preventive maintenance training every six months and every two years, and two respondents run preventive maintenance training every three months. There are also laboratories (2 respondents) that do not have a fixed schedule to carry out preventive maintenance training if they have the budget. However, six respondents stated that they did not carry out preventive maintenance training. Table 4 shows that the Interval for Preventive Maintenance Training depends on the difficulty level of the Laboratory equipment.

Table 4. Interval for Preventive Maintenance Training depends on the difficulty level of the Laboratory equipment

Interval for Preventive Maintenance Training	Number of Laboratory
3 Monthly	2
6 Monthly	3
1 Yearly	14
2 Yearly	3
Depend on Funds	2
Not Planned	6

Standardization of Maintenance Activities

Based on the survey results, 26 laboratories have standard operating procedures (SOP) and four laboratories that do not have SOPs in carrying out maintenance. The period for evaluating the SOP is divided into several groups, as shown in Table 5. Generally, the evaluation of the SOP for the implementation of maintenance is carried out once every year, with 17 respondents answering. In addition, there is also one Laboratory that will evaluate if it has a budget. However, some laboratories do not evaluate SOPs at all.

Table 5. SOP Evaluation Schedule

Description	Number of Laboratory	% of Laboratory
Every 1x in a year	17	57%
Every 1x in two years	5	17%
Every 1x in five years	3	10%
Depend on funds	1	3%
Never been evaluated	4	13%

Maintenance Period

The survey results show that the long-term and short-term planning periods carried out by each Laboratory, as shown in Table 6. In the long-term planning period, there are eight laboratories doing planning for two years, five laboratories doing planning for three years, and 13 laboratories doing planning for five years. While three laboratories carry out long-term planning depending on available funds, and one Laboratory has not planned long-term planning.

Meanwhile, 16 laboratories are conducting short-term planning for one year, ten laboratories for six months, one Laboratory for one month, and three are not executing short-term planning.

Table 6. Maintenance Period

Planning Type	Description	Number of Laboratory
Long-Term	2 years	8
	3 years	5
	5 years	13
	Depend on funds	3
	Not planned	1

Planning Type	Description	Number of Laboratory
Short-Term	1 months	16
	6 months	10
	1 year	1
	Not executing	3

Maintenance Technique

Maintenance Techniques can be done through an assessment of the condition of the components. The use of assessment data documentation is to facilitate component analysis. Maintenance Activities Documentation can be done by documenting using a list and standard form and documented by writing on empty papers. Based on the table 7, 24 laboratories carry out documentation using a list and standard form. In comparison, four laboratories record their data by writing on empty papers, while two other laboratories have no documentation. In general, 80% of the 30 laboratories surveyed have used a proper method to record and assess their components' conditions. The ability of maintenance techniques also was measured each Laboratory in detecting failure and damages. We can conclude that two laboratories had meager abilities, seven had low abilities, 19 had high abilities, and two had very high abilities.

Table 7. Maintenance Activities Documentation

Maintenance Activities Documentation	Number of Laboratory	% of Laboratory
Documented using list and standard form	24	80%
Documented by writing on empty papers	4	13%
There is no documentation	2	7%

Spare Part Management

Based on the survey results, most laboratories carry out the procurement when they run out of stocks or reach a certain amount. The laboratories choose to do this spare part management since the required number of spare parts has been considered in the scheduling of the Laboratory activities (shown at Table 8). Hence, the Laboratory never really ran out of spare parts when the failure of tools occurred in the middle of their activities.

Information Management Systems

Most of the laboratories store their component assessment and failure data on computers (as shown in Table 9). Only 7 out of 30 laboratories use paper files, and the rest did not keep track of their assessment data. Storing the data on a computer is considered the most practical choice and also more accessible for the laboratories to edit or find the required data at a specific time. Some respondents who use paper files think that it is faster than computers and still have not mastered the computer features. The Laboratory does not store data because they do not have many spare parts to track.

Table 8. Spare Part Management

Material and Spare Parts Management	Number of Laboratory	% of Laboratory
Procurement is carried out when reach certain amount	2	6.7%
Procurement is carried out on certain period	12	40.0%
Procurement is carried out when the stocks are out	13	43.3%
There is no Material and Spare Parts Management	3	9.4%

Table 9. Information Management Systems

Component Condition Assessment Data Storage	Number of Laboratory	% of Laboratory
Computer (Microsoft Excel, Word, etc..)	2	7%
Paper Files	7	23%
Using Assessment Software	19	63%
No storage	2	7%
No data needs to be stored	0	0%

Cost Structure

The cost structure observed in this survey as shown in consists of Material/component replacement costs, Maintenance service costs, Specific maintenance equipment costs, and repair procedures evaluation costs. The results of the survey regarding the cost structure in the Laboratory are shown in Figure 3. Of the 30 laboratories, only seven laboratories compile four cost structures in maintenance activities in the Laboratory, while eight laboratories prepare Material/component replacement, Maintenance service, and Specific maintenance equipment costs, two laboratories prepare Materials /component replacement and Repair procedures evaluation costs, three laboratories prepare Material/component replacement costs, Maintenance service costs, three laboratories prepare Material/component replacement costs, and Specific maintenance equipment costs. Even one of the laboratories does not clarify costs because it depends on the laboratory leadership. In general, the cost structure for maintenance activities has been prepared in each Laboratory, although there is one Laboratory whose cost structure is unclear.

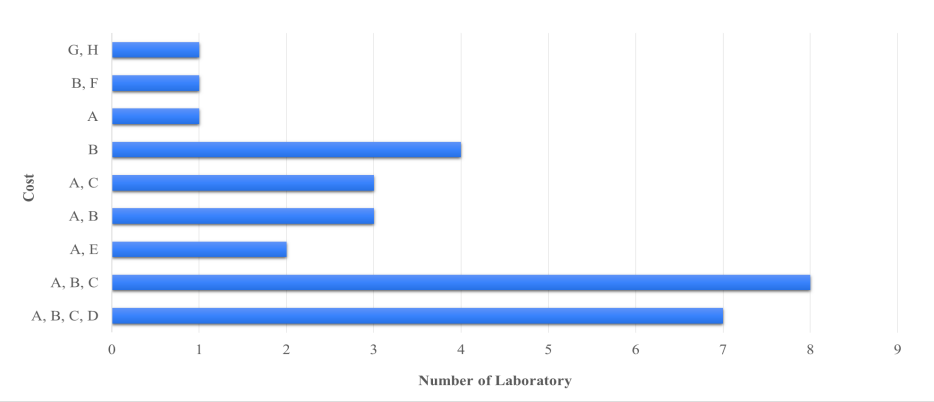

Figure 3. Cost Structure

Note: A=Material/component replacement costs, B= Maintenance service costs, C=Specific maintenance equipment costs, D= Repair procedures evaluation cost, E= Repair procedures evaluation costs, F= Lab equipment calibration service costs, G= The cost is not clear, and H= Depends on the leader.

Failure and Downtime

Based on the 30 laboratories surveyed, two of them have very high maintenance technique ability, and 20 of them have high enough maintenance technique ability. We can conclude that 74% of the 30 laboratories have good maintenance technique abilities. Meanwhile, 7 of them have pretty low maintenance technique abilities and one very low Laboratory. Thus, 26% of them still had low maintenance technique abilities. Table 10 shows Maintenance Technique Ability in 30 laboratories.

Table 10. Maintenance Technique Ability

Maintenance Technique Ability	Number of Laboratory	% of Laboratory
Very Low	1	3%
Pretty low	7	23%
High enough	20	67%
Very High	2	7%

Failure and downtime characteristics can also be observed from how long failure and downtime occur during Laboratory activities. The length of time for failure and downtime of 30 laboratories is shown in Figure 4. Based on the figure, there are four laboratories with no extended downtime (5-10 minutes), 12 laboratories with a moment of downtime (10-30 minutes), five laboratories with a pretty extended downtime (30-60 minutes), and nine laboratories with very long downtime (>1 hour). Most laboratories have short downtime, but the number of very long downtime needs to be considered.

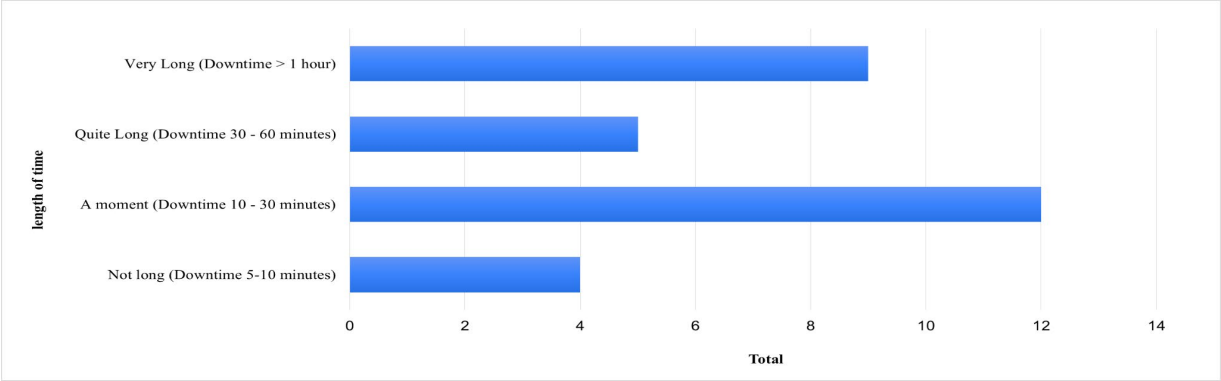

Figure 4. Length of Time for Failure and Downtime

5.2 The Current Situation of Preventive Maintenance Implementation in Laboratory

This study tries to summarize the current situation of preventive maintenance implementation based on the survey findings with categorizing laboratories into four groups, that is:

1. Poor Implementation refers to those organizations who do not or less implement characteristic of preventive maintenance
2. Fair Implementation refers to those organizations that implement few characteristics of preventive maintenance.
3. Good Implementation refers to those organizations that implement more characteristics of preventive maintenance.
4. Excellent Implementation refers to those organizations that implement fully or almost entirely preventive maintenance's characteristics.

Table 11 shows that the category of 73% of laboratories is excellent implementation, and 27% of laboratories is exemplary implementation. Moreover, there is no Laboratory with poor implementation and fair implementation. It means that most laboratories have already implemented preventive maintenance in their maintenance strategy.

Table 11. Summary Categorize of Laboratory

Categorize	Number of Laboratory	% of Laboratory
Poor Implemented	0	0%
Fair Implemented	0	0%
Good Implemented	8	27%
Excellent Implemented	22	73%
Total	30	100%

In addition, Figure 5 shows a radar diagram for the current status of preventive maintenance implementation in Laboratories. The diagram shows us eight characteristics of preventive maintenance implementation. In each area, there are four groups of respondents. The percentage shown in each sector represents the number of respondents who meet the characteristics of each group based on variable measurement in the data collection section. The red bullet shows the average status of preventive maintenance implementation in the Laboratory. The radar diagram shows that the laboratories fully implement almost all characteristics of preventive maintenance. However, there is room for improvements, especially for spare part management.

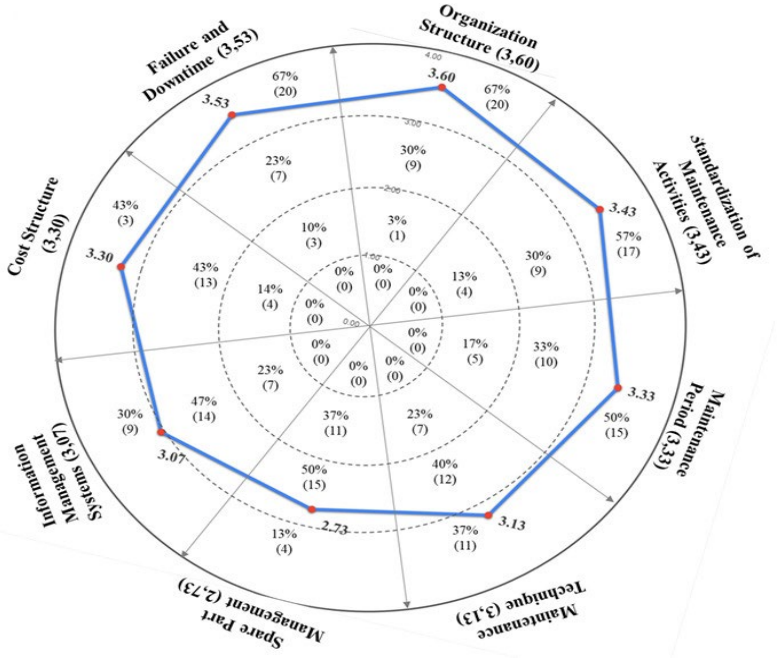

Figure 5. Radar diagram of for current status of preventive maintenance implementation in Laboratories

6. Conclusion

Preventive maintenance is defined as maintenance intended to assess and mitigate degradation and reduce the probability of failure of an item. Therefore, the implementation of preventive maintenance must be a priority in the maintenance strategy in the Laboratory. Based on the survey results, the characteristics of the implementation of

preventive maintenance of laboratories owned by the government and state universities in Indonesia were found that 26 laboratories have standard operating procedures (SOPs) and four laboratories that do not have SOPs in carrying out maintenance. In general, the Laboratory has prepared long-term planning and short-term planning in its maintenance activities. The maintenance technique used by the Laboratory is generally documented using a list and a high standard form and ability of maintenance technique. Most laboratories carry out the procurement when they run out of stocks or reach a certain number of stocks. Most of the laboratories store their component assessment and failure data on computers. The cost structure for maintenance activities has been prepared in each Laboratory, although there is one Laboratory whose cost structure is unclear. 74% of the 30 laboratories have good maintenance technique abilities, and 26% still have low maintenance techniques. Most laboratories have short downtime, but the number of very long downtimes needs to be considered. The currect status of maintenance implementation in 30 laboratories found that 73% of laboratories are categorized as excellent implementation and 27% of laboratories are categorized as exemplary implementation. Moreover, there is no laboratory with poor implementation and fair implementation. It means that most laboratories have already implemented preventive maintenance in their maintenance strategy.

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Biography

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